

Electronic Prescribing: An Examination of Cost Effectiveness, Clinician Adoption and Limitations

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Abstract E-prescribing has flourished due to the promise of improving efficiency and decreasing prescription errors caused by its handwritten counterpart, yet only 44% of doctor's offices use paperless prescriptions. Many studies have assessed the value of e-prescribing in the clinical setting, yet there is no all-inclusive summation of these findings. The aim of this study was to review the literature within the last decade pertaining to the cost effectiveness, clinician adoption and limitations of e-prescribing. Journal articles from January 1, 2003 through May 1, 2013 were compiled through use of the search engines: PubMed, International Pharmaceutical Abstracts (IPA), and Google Scholar. A total of 56 peer-reviewed articles were included in this review. Trends show that most clinicians view e-prescribing positively despite some limitations. Limitations of e-prescribing include cost of implementation and maintenance, insufficient training, and lack of standardization. The cost to implement an integrated system with alerts and decision support is \$29,000 per physician for the first year and \$4,000 every year thereafter. Furthermore, e-prescribing has little disruption to workflow and no statistically significant increase in processing time. Although limitations exist, an expansion of e-prescribing is expected in the future. Efforts should be increased to promote clinicians adopting e-prescribing.

Keywords E-Prescribing, Pharmacy Informatics, Clinical Pharmacist, HITECH Act, and Computerized Provider Order Entry (CPOE)

1. Introduction

Electronic prescribing (or e-prescribing) is the electronic transmission of prescriptions or prescription-related information between a prescriber, dispenser, pharmacy benefit manager, or health plan [21]. In the last 10 years, the use of e-prescribing has flourished due to the promise of improving efficiency and decreasing prescription errors

caused by its handwritten counterpart, yet according to 2012 estimates, only 44% of doctor's offices use paperless prescriptions [1,2,3]. However, this is a drastic increase from 12% utilization in 2009. While there was initial opposition towards e-prescribing due to perceptions of increased costs, training requirements, and time constraints, many studies have been published to address those concerns. For example, many clinicians felt that the use of e-prescribing would disrupt workflow and take more time. However, it has been shown that e-prescribing actually saves time and can be implemented into the workflow with proper training [4, 5]. The purpose of this review was to discuss e-prescribing as a preferred form of prescribing and its current impact. With the Medicare Modernization Act of 2003 pushing for e-prescribing and many other insurers following suit, this article summarizes the present state of e-prescribing and its future utilization [6]. In addition, the importance of clinician acceptance of electronic prescribing and methods to improve integration are discussed. Clinical pharmacists have an opportunity to detect prescribing errors and improve prescription quality through the use of electronic prescribing. Furthermore, electronic prescribing has been used to monitor and assess patient compliance and prescription discrepancies [23]. Several studies show that electronic prescribing has been shown to reduce prescribing errors in United States hospitals [49,50,51,52,53,54]. However, there is no consensus on best practices in the use of electronic prescribing. Further research is needed to explore implementation of electronic prescribing within hospital systems considering that only 67% of eligible users were utilizing electronic health records (EHR) in 2012, and an even lower percentage for electronic prescriptions [7]. With more prescribers utilizing electronic prescribing and pharmacists processing electronic prescriptions over the next few years, more analysis of e-prescribing methods can be made and best practices can be developed. These assessments can help patients reach disease state goals and help clinicians reach the overall goal to enhance patient care through better integration and communication between the patient, pharmacist and physician [18,23, 24].

2. Materials and Methods

Journal articles were compiled through use of the following search engines: PubMed, International Pharmaceutical Abstracts (IPA), and Google Scholar. The key terms utilized were: 'future AND e-prescribing', 'future AND pharmacy informatics', 'e-prescribing AND limitations', 'clinical pharmacist AND e-prescribing', 'HITECH act AND electronic prescribing' and 'computerized provider order entry (CPOE).'

Articles selected for review were published from January 1, 2003 through May 1, 2013 (Table 1, Table 2). The articles required information on e-prescribing; particularly, articles pertaining to cost-effectiveness, limitations, clinician perception and future needs. Articles pertaining to pharmacy or the use of pharmacy informatics were also utilized as a secondary search and mainly focused on U.S. data. However, international studies were utilized to characterize crucial points or opinions about e-prescribing. Subsequent related U.S. articles were then searched to support those claims.

Articles were excluded from the search if they were written in or prior to 2002. Articles that concentrated on the utilization of electronic health records were also excluded as the primary objective was to review e-prescribing. An exception was two studies on public attitudes on electronic health records and studies that discussed the e-prescribing process. Finally, cost-effectiveness studies completed internationally were excluded since the values reported in the studies could not be accurately extrapolated to U.S. dollars. Once articles were retrieved, they were evaluated based on the Oxford Centre for Evidence-Based Medicine (Table 1). Next, they were summarized into tables based on subtopic (cost effectiveness, clinician adoption, and limitations), which were further organized by noting the year published, author(s), title, study design, intervention, findings, source for each study, and study grade (Table 2, 3, 4). The articles were assessed for quality by a second author to ensure that all articles met the inclusion criteria.

Table 1. Level of evidence for rating studies and grading recommendations, as per the Oxford Centre for Evidence-based Medicine (OCEBM)

Level	Type of evidence
1a	Systematic review with homogeneity of randomized control trials
1b	Individual randomized control trial with a narrow confidence interval
1c	All or none related outcome
2a	Systematic review with homogeneity of cohort studies
2b	Individual cohort study (including low-quality randomized control trials, e.g. less than 80% follow-up)
2c	"Outcomes" Research; Ecological studies
3a	Systematic review with homogeneity of case-control studies
3b	Individual case-control study
4	Case-series (and poor-quality cohort and case-control studies)
5	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"
Grades of recommendation	
A	Consistent with level 1 studies
B	Consistent level 2 or 3 studies or extrapolations from level 1 studies
C	Level 4 studies or extrapolations from level 2 or 3 studies
D	Level 5 evidence or troublingly inconsistent or inconclusive studies of any level

Table 2. Summary of Articles:Cost effectiveness

Year	Author	Title	Design	Intervention	Findings	Source	Study Grade
2003	Bartlett, Tamblyn, Huang, Kawasumi, Petrella, Dufour	Evaluation of Standardized Tasks for Primary Care Physicians Using the MOXXI Electronic Prescribing and Integrated Drug Management System	Prospective t-test	Administering and timing the completion of a series of tasks by a physician after a 2 week training program	<ul style="list-style-type: none"> Physicians were given a training session with the e-prescribing software using mock patients. They were then evaluated on how quickly and efficiently they were able to redo those tasks on their own. Physicians were able to quickly complete all tasks but only had difficulty with changing the status of a problem or with renewing multiple prescriptions at once 	AMIA Annual Symposium Archive	A
2003	Corley	Electronic prescribing: a review of costs and benefits	Analysis	None	<ul style="list-style-type: none"> Improved physician, nurse and staff efficiency calculated using time trial comparisons between paper and e-prescribing E-prescribing software is cost-effective for all size practices with a more rapid ROI in larger practices 	Topics in Health Information Management	B
2003	Fischer, Stewart, Mehta, Wax, Lapinsky	Handheld Computing in Medicine	Systematic review of literature	Summary of articles and current literature to provide evidence-based information	<ul style="list-style-type: none"> Enough information was collected to create an article to increase awareness amongst physicians about the potential roles for portable devices and to call for further evaluation for the benefit of use 	Journal of American Medical Informatics Association	B
2004	Tanne	Electronic prescribing could save at least \$29 billion	Analysis article	None	<ul style="list-style-type: none"> Assessment of physicians sending eRx to pharmacies Cost in savings from preventing duplications from multiple doctors Cheaper prescription options and alert about interactions and incorrect dosages with clinical decision support Downstream savings of \$2 billion from preventing errors that would result in doctor visits or hospital stays 	British Medical Journal	B
2005	Pizzi, Suh, Barone and Nash	Factors related to physicians' adoption of electronic	Quantitative study	Electronic survey	<ul style="list-style-type: none"> 1,104 responses recorded 19% of responses from 	American Journal of Medical Quality	A

		prescribing: results from a national survey			physicians who used e-prescribing		
2007	Donyai, O'Grady, Jacklin, Barber, Franklin	The effects of electronic prescribing on the quality of prescribing	Prospective intervention analysis	Recording of pharmacy interventions during a 4 week period before and after implementation of electronic prescribing	<ul style="list-style-type: none"> Adoption can be stimulated by improvements in the technology and an organizational commitment UK study E-prescribing reduced pharmacist intervention (73 →45) as well as prescribing errors (94 → 48) Pharmacy needs to develop ways to complement use of electronic prescribing rather than duplicate the benefits of it 	British Journal of Clinical Pharmacology	B
2007	Foxhall	E-prescribing goes to Washington. With the federal government behind it, electronic prescribing is gaining speed, weight, and more standards	Report	None	<ul style="list-style-type: none"> Medicare incentives are pushing for e-prescribing In 2013, there will be a 1.5% Medicare Part B payment adjustment to physicians if e-prescribing is not utilized. In 2014, that adjustment goes up to 2%. 	Healthcare informatics	D
2007	Gerstle, Lehmann	Electronic prescribing systems in pediatrics: the rationale and functionality requirements	Technical report	Report discusses use of e-prescribing in pediatrics	<ul style="list-style-type: none"> Evaluates e-prescribing in all aspects (from costs to technical issues) 	Pediatrics	B
2007	Grossman, Gerland, Reed and Fahlman	Physician's experiences using commercial e-prescribing systems	Discussion	44 discussions from respondents in two-person teams in 26 organizations via telephone	<ul style="list-style-type: none"> 2/3 of practices used EMR (integrated system) 1/3 stand-alone system Issue with maintaining patient medication lists Lack of decision support Difficulty obtaining accurate patient-specific formulary information Limited connectivity with pharmacies and mail-order PBMs Not enough staff to maintain and support IT after implementation All respondents believe e-prescribing improves safety and quality while increasing practice efficiency 	Health Affairs	B
2007	Hollingworth, Devine,	The Impact of e-prescribing	Cross-sectional	Time-motion methods to	<ul style="list-style-type: none"> No statistically significant 	Journal of American	B

	Hansen, Lawless, Comstock, Wilson-Norton, Tharp, Sullivan	on Prescriber and Staff Time in Ambulatory Care Clinics: A Time-Motion Study	comparison study	track staff and prescriber tasks while using an integrated system	increase in time taken to e-prescribe versus handwritten prescriptions. ●E-prescribing has no disruption to workflow and therefore that reason can't be seen as a barrier to adopting e-prescribing practices.	Medical Informatics Association	
2007	Scalise	The case for e-prescribing	Analysis	None	<ul style="list-style-type: none"> ● Lost productivity due to time required to print PDA generated prescriptions and fax pharmacies (applies to controlled medications) ● Program functionality confusion ● Cost – software/hardware cost ranges from \$1,500 - \$4,000/physician ● Advanced systems with complex alerts and reminders are \$29,000/physician in the first year and \$4,000 annually thereafter ● Waiting for an all-in-one solution before investing in a product 	Hospital and Health Networks	B
2008	Devine, Wilson-Norton, Lawless, Hansen, Hollingworth, Fisk, Sullivan	Implementing an Ambulatory e-Prescribing System: Strategies Employed and Lessons Learned to Minimize Unintended Consequences	Analysis	None	<ul style="list-style-type: none"> ● CPOE improves quality of care and reduces med errors ● Need an integrated, community-based system for adoption ● Need for ongoing training ● Key is team-oriented culture (bridge between all points of healthcare) 	Advances in Patient Safety: Alternative Approaches (Volume 4: Technology and Medication Safety)	B
2008	Fischer, Vogeli, Stedman, Ferris, Brookhart, Weissman	Effect of electronic prescribing with formulary decision support on medication use and cost	Pre-post study with concurrent controls	Analysis of administrative data in 2 large Massachusetts insurers	<ul style="list-style-type: none"> ● Reduced spending on medications due to formulary decision support ● Physicians more likely to prescribe tier 1 drugs ● \$845,000/100,000 patients saving 	Archives of Internal Medicine	A
2008	Rupp, Warholak	Evaluation of e-prescribing in chain community pharmacy practice recommendations	Descriptive, nonexperimental, cross-sectional study	Self-administered survey and interviews of key pharmacy operations and information technology management	<ul style="list-style-type: none"> ● 1,094 surveys returned. ● E-prescriptions were preferred in each of the 7 desired outcomes of care. ● Benefits: legibility, improved speed on efficiency of processing 	Journal of the American Pharmacists Association	B

					Disadvantage: prescribing errors due to lack of training		
2009	Balfour, Evans, Januska, Lee, Lewis, Nolan, Noga, Stemple, Thapar	Health Information Technology – Results from a Roundtable Discussion	Discussion	None	<ul style="list-style-type: none"> Challenges to adoption of e-prescribing are high costs, resistance to change, misaligned incentives and fractured payment system Benefits: avoid costs from adverse drug events Impact on cost exceed a saving of \$800 million over a 5 year period by prescribers, dispenses and beneficiaries E-rx transactions have risen 3x from 2007 to 2008 with over 100 million transactions (started with 700,000 in 2004) 	JMCP	C
2009	Smith, Dang, Lee	E-prescribing: Clinical Implications for Patients with Diabetes	Analysis	None	<ul style="list-style-type: none"> Mentions movement and utilization of e-prescribing to help pharmacy with reduction of errors and clinical decision support Help reaching diabetes goals Indications of drug interactions and importance of complete medication profile Cases to prove potential adverse interactions or incorrect dispensing 	Journal of Diabetes Science and Technology	C
2010	Brooks, Sonnenschien	E-prescribing: where health information and patient care intersect	Analysis	None	<ul style="list-style-type: none"> MTM can help reduce rising costs of healthcare E-prescribing allows for most medically appropriate and cost effective prescription at point of care and transmitting to patient's pharmacy of choice Makes process more efficient 	Journal of Healthcare Information Management	D
2010	Kaushal, Kern, Barron, Quaresimo, Abramson	Electronic Prescribing Improves Medication Safety in Community-Based Office Practices	Prospective, non-randomized study	Use of commercial, stand-alone e-prescribing system with clinical decision support including dosing recommendations and checks for drug-allergy interactions, drug-drug interactions and duplicate therapies	<ul style="list-style-type: none"> Error rates when changed to e-prescriptions after a year follow-up showed a sevenfold decrease in error rates compared to those who stayed with paper prescriptions. 	Journal of General Internal Medicine	B

2011	Kannry	Effect of e-prescribing systems on patient safety	Overview study	None	<ul style="list-style-type: none"> Limited evidence suggests that e-prescribing with medical decision support can improve patient safety Medicare and Medicaid incentives to push for e-prescribing E-prescribing as its own source of medication error 	The Mount Sinai Journal of Medicine	C
2011	Liu, Burkhart, Bell	Evaluation of the NCPDP Structured and Codified Sig Format for e-prescriptions	Retrospective cross-sectional study	Evaluation of ambulatory e-prescriptions based on the actual words used by prescribers in the sig field to the equivalent terms in the designated terminology	<ul style="list-style-type: none"> 95% of sigs were correctly represented Some ambiguities – but mainly from multi-step instructions Most errors were administration timings and dose delivery methods 	Journal of the American Medical Informatics Association	B
2011	Michelis, Hassouna, Owlia, Kelahan, Young, Choi	Effect of electronic prescription on attainment of cholesterol goals	Retrospective cohort study	Query of 796 patients not at LDL goal at baseline	<ul style="list-style-type: none"> Patients receiving an eRX were 59% more likely to achieve LDL goal Reasons may be due to formulary decision support and lower cost of medications For every \$10 increase in prescription price, the likelihood of being at goal decreased by 5% 	Clinical Cardiology	B
2012	Gilligan, Miller, Mohney, Montenegro, Schwarz, Warholak	Analysis of pharmacists' interventions on electronic versus traditional prescriptions in 2 community pharmacies	Observational prospective design	Collect and examine data from 2 community chain pharmacies	<ul style="list-style-type: none"> 1,678 new prescriptions were reviewed and 153 needed intervention over a 13 day period 11 hours and 58 minutes were spent on the interventions Reasons for intervention: excessive quantity/duration and violating legal requirements Difference in intervention rate between e-prescribing and handwritten prescriptions were not statistically significant 	Research in Social and Administrative Pharmacy	A
2012	McBride	E-prescribing prevents errors	Analysis	None	<ul style="list-style-type: none"> 67% of physicians are e-prescribing Point of e-prescribing is to give more data to have better safety checks and not save time Vital communication link between physician, pharmacists and patients 	Medical Economics	C

2012	Surescripts	E-prescribing shown to improve outcomes, save billions	Post-hoc quantitative study	Collaboration between Surescripts, pharmacies, and PBMs to quantify de-identified data sets to measure impact on first-fill medication adherence.	<ul style="list-style-type: none"> • Evaluation of data from 2008-2010 • Physicians who adopted e-prescribing has 10% increase in first-fill medication adherence • Physicians who utilized e-prescribing used the technology route for up to 40% of their prescriptions • E-prescribing directly to the pharmacy showed a 11.7% increase in the number of prescriptions that make it to the pharmacy • Increase in adherence will save medical costs downstream in the amounts of \$3-\$10 for a potential total of \$140 billion dollars in savings over the next 10 years. 	Health Management Technology	B
2012	Westbrook, Reckmann, Li, Runciman, Burke, Lo, Baysari, Braithwaite, Day	Effects of two commercial electronic prescribing systems on prescribing error rates in hospital in-patients: a before and after study	Before and after study	Medication chart audit of 3,291 admissions	<ul style="list-style-type: none"> • Australian study at two hospitals • Controls were wards in same two hospitals that did not use electronic prescribing • Procedural and clinical errors were identified and the severity measured • Reductions in prescribing errors seen • Clinical error reductions were limited due to lack of substantial decision support but decline in serious errors 	PLOS Medicine	B
2013	Radley, Wasserman, Olsho, Shoemaker, Spranca, Bradshaw	Reduction in medication errors in hospitals due to adoption of computerized provider entry systems	Systematic literature review and meta-analysis	None	<ul style="list-style-type: none"> • CPOE decreases likelihood of an error on an order by 48% • 12.5% reduction in medical errors (~17.4 million/year) • Only analyzed for acute-care inpatient setting • Unclear if this translates to reduced harm to patients • Data from 2006-2008 from 4,701 hospitals 	Journal of American Medical Informatics Association	B

Table 3. Summary of Articles: Clinician Adoption

Year	Author	Title	Design	Intervention	Findings	Source	Study Grade
2003	Bartlett, Tamblyn, Huang, Kawasumi, Petrella, Dufour	Evaluation of Standardized Tasks for Primary Care Physicians Using the MOXXI Electronic Prescribing and Integrated Drug Management System	Prospective t-test	Administering and timing the completion of a series of tasks by a physician after a 2 week training program	<ul style="list-style-type: none"> Physicians were given a training session with the e-prescribing software using mock patients. They were then evaluated on how quickly and efficiently they were able to redo those tasks on their own. Physicians were able to quickly complete all tasks but only had difficulty with changing the status of a problem or with renewing multiple prescriptions at once 	AMIA Annual Symposium Archive	A
2005	Galt, Siracuse, Rule, Clark, Taylor	Physician Use of Hand-held Computers for Drug Information and Prescribing	Randomized, controlled trial	Primary care physicians were given a PDA to prescribe and the error rates were assessed	<ul style="list-style-type: none"> Use for hand-held devices show some validity Physicians feel that they can see more patients Important to have positive learning-related attitude Proper training needed 	Advances in Patient Safety: From Research to Implementation (Book)	B
2005	Pizzi, Suh, Barone and Nash	Factors related to physicians' adoption of electronic prescribing: results from a national survey	Quantitative study	Electronic survey	<ul style="list-style-type: none"> 1,104 responses recorded 19% of responses from physicians who used e-prescribing Adoption can be stimulated by improvements in the technology and an organizational commitment 	American Journal of Medical Quality	A
2007	Gerstle, Lehmann	Electronic prescribing systems in pediatrics: the rationale and functionality requirements	Technical report	Report discusses use of e-prescribing in pediatrics	<ul style="list-style-type: none"> Evaluates e-prescribing in all aspects (from costs to technical issues) 	Pediatrics	B
2007	Grossman, Gerland, Reed and Fahlman	Physician's experiences using commercial e-prescribing systems	Discussion	44 discussions from respondents in two-person teams in 26 organizations via telephone	<ul style="list-style-type: none"> 2/3 of practices used EMR (integrated system) 1/3 stand-alone system Issue with maintaining patient medication lists Lack of decision support Difficulty obtaining accurate patient-specific formulary information Limited connectivity with pharmacies and mail-order PBMs 	Health Affairs	B

					<ul style="list-style-type: none"> ● Not enough staff to maintain and support IT after implementation ● All respondents believe e-prescribing improves safety and quality while increasing practice efficiency 		
2008	Fischer, Vogeli, Stedman, Ferris, Brookhart, Weissman	Effect of electronic prescribing with formulary decision support on medication use and cost	Pre-post study with concurrent controls	Analysis of administrative data in 2 large Massachusetts insurers	<ul style="list-style-type: none"> ● Reduced spending on medications due to formulary decision support ● Physicians more likely to prescribe tier 1 drugs ● \$845,000/100,000 patients saving 	Archives of Internal Medicine	A
2008	Rupp, Warholak	Evaluation of e-prescribing in chain community pharmacy practice recommendations	Descriptive, nonexperimental, cross-sectional study	Self-administered survey and interviews of key pharmacy operations and information technology management	<ul style="list-style-type: none"> ● 1,094 surveys returned. ● E-prescriptions were preferred in each of the 7 desired outcomes of care. ● Benefits: legibility, improved speed on efficiency of processing Disadvantage: prescribing errors due to lack of training 	Journal of the American Pharmacists Association	B
2010	Desroches, Agarwal, Angst, and Fischer	Differences between integrated and stand-alone E-prescribing systems have implications for future use	Qualitative analysis	Surveyed physicians about use of e-prescribing in an outpatient setting	<ul style="list-style-type: none"> ● Physicians with access to patient's drug history were more likely to review it before prescribing a new medication. ● This percentage was higher in those using integrated systems. 	Health Affairs (Milwood)	B
2010	Tseng, Brook, Alexander, Hixon, Dudley, et al.	Health Information Technology and Physician's Knowledge of Drug Costs	Descriptive, nonexperimental, cross-sectional study	Statewide survey of 247 primary care physicians regarding IT use and self-reported knowledge of formularies, copayments, and retail prices	<ul style="list-style-type: none"> ● 80% of physicians used IT but less than 20% knew drug costs. ● Less than 10% knew about formularies. ● Recommendation: IT design to consider easily accessible cost information at point of care 	American Journal of Managed Care	B
2011	Frolich, Zorina, Fontana, Kullak-Ublick, Vollenweider, Russmann	Evaluation of medication safety in the discharge medication of 509 surgical inpatients using electronic prescription support software and an extended operational interaction classification	Cross-sectional study	Retrospective identification of drug interactions in patients' discharge medication	<ul style="list-style-type: none"> ● 2,558 of 2,729 prescriptions generated interaction alerts and 1,849 comments ● 10 high danger (contraindications) based on ORCA criteria ● 551 average danger alerts based on ORCA criteria (77 provisionally contraindicated combos, 310 conditional and 164 minimal risk of adverse 	European Journal of Clinical Pharmacology	B

					<p>outcomes)</p> <ul style="list-style-type: none"> ● 56 did not have recommended dose adjustment for impaired renal function ● Need to reduce over-alerting and improve usability to be more efficacious in preventing adverse drug events 		
2011	Gaylin, Moiduddin, Mohamoud, Lundeen, Kelly	Public attitudes about health information technology, and its relationship to health care quality, costs and privacy	Multivariate logistic regression analysis	Random-digit-dial sample telephone survey and interview	<ul style="list-style-type: none"> ● 78% of responses favored use of electronic medical records and could improve care and reduce costs ● Benefits outweigh privacy risks 	Health Service Research	A
2011	Grossman, Cross, Boukus, Cohen	Transmitting and processing electronic prescriptions: experiences of physician practices and pharmacies	Qualitative analysis	Telephone interviews with physician practices, community pharmacies and mail order pharmacies using Surescripts	<ul style="list-style-type: none"> ● Most parties were satisfied with the use of electronic transmission but there were system limitations that prevented electronic transmission and required a fax or phoned in prescription. ● Inconsistent renewal processes by physicians required pharmacy staff to complete or edit fields 	Journal of American Medical Informatics Association	B
2011	Lapane, Rosen, Dube	Perceptions of e-prescribing efficiencies and inefficiencies in ambulatory care	Mixed method study design using qualitative data	Focus groups reported back via survey on one of six software packages. Results were analyzed and coded using NVivo software	<ul style="list-style-type: none"> ● 64% physicians viewed e-prescribing as very efficient. ● Next preferred at 25% was computer generated fax. 	International Journal of Medical Informatics	B
2011	Spina, Glassman, Simon, Lanto, Lee, Cunningham, Good	Potential safety gaps in order entry and automated drug alerts: a nationwide survey of VA physician self-reported practices with computerized order entry	Cross-sectional study	National survey of VA physicians containing 35 questions in 4 domains	<ul style="list-style-type: none"> ● 90% felt improved prescribing safety ● 48% felt critical drug-drug interactions as useful ● Medical specialists found less useful 	Medical Care	B
2012	Crosson, Schueth, Issacson and Bell	Early adopters of electronic prescribing struggle to make meaningful use of formulary checks and medication history documentation	Multimethod comparative case study	Observation of prescription workflow during implementation of stand-alone e-prescribing program and conduction of interviews with physicians and staff	<ul style="list-style-type: none"> ● Incomplete or challenges with formulary checks or patient history documentation led to prescriber distrust ● Further leads to unwillingness to rely on e-prescribing-based information and prefers dependence on paper charts ● Greater data accuracy and completeness required to improve safety and efficacy 	Journal of the American Board of Family Medicine	B
2012	Odukoya, Chui	Relationship between	Cross-sectional	Thinking aloud protocols	<ul style="list-style-type: none"> ● Two factors influencing 	Journal of the	B

		e-prescriptions and community pharmacy workflow	qualitative study	and pharmacy group interviews of 16 pharmacists and 14 pharmacy technicians	workflow: software issues and informal training	American Pharmacists Association	
2012	Thomas, Kim, McDonald, Kreiner, Kelleher, Blackman, Kaufman, Carrow	Prescribers' expectations and barriers to electronic prescribing of controlled substances	Survey	On-site interviews with physicians and providers regarding e-prescribing controlled substances.	<ul style="list-style-type: none"> • 246 practitioners participated with 63% male and 90% white. • Most issues were due to errors, pharmacy call-backs, diversion. <ul style="list-style-type: none"> • Physicians found that expectation to carrying a security authentication token at all times would be burdensome and deter from adopting e-prescribing. 	Journal of American Medical Informatics Association	A
2012	Weingart, Mattsson, Zhu, Shulman, Hassett	Improving Electronic Oral Chemotherapy Prescription: Can We Build a Safer System?	Prospective study	Review of generated electronic prescriptions for surveyed ease of use	<ul style="list-style-type: none"> • 6,673 prescriptions generated using weight and BSA-based dosing. • 5% of prescriptions generated dose-limit warnings but were disregarded by physicians because current dosing recommendations exceeded dose-limit warnings. <ul style="list-style-type: none"> • Clinicians still needed to customize their directions using the free text field for 64% of the prescriptions. 	Journal of Oncology Practice	A
2013	Ancker, Silver, Miller, Kaushal	Consumer experience with and attitudes towards health information technology: a nationwide survey	Multivariate logistic regression analysis	Random digit-dial survey of 1,603 eligible participants	<ul style="list-style-type: none"> • n= 1,000 participation • 66% positive view on EHR and its likelihood to improve quality of care; 79% positive view on health information exchange • Not associated with privacy concerns 	Journal of the American Medical Informatics Association	A
2013	Jariwala, Holmes, Banahan, McCaffrey	Factors that physicians find encouraging and discouraging about electronic prescribing: a quantitative study	Quantitative study	Cross-sectional study using an internet-based survey to a national sample of primary care physicians	<ul style="list-style-type: none"> • 443 surveys received • Pre-implementation and cost factors found to be most discouraging • Software features most encouraging • Facilitation of adoption depends on targeting factors that are salient to physicians 	Journal of American Medical Informatics Association	A
2013	Johnson, Lehmann	Electronic prescribing in pediatrics: toward safer and more effective medication management	Technical report	Review of pediatric data	<ul style="list-style-type: none"> • Limited data for role of e-prescribing • Existing data shows positive response for mitigating med 	Pediatrics	C

					errors, improve communication with pharmacy and better medication adherence <ul style="list-style-type: none"> American Academy of Pediatrics recommends the adoption of e-prescribing systems with pediatric functionality 		
2013	Thomas, Kim, Kelleher, Nikitin, Kreiner, McDonald, Carrow	Early experience with electronic prescribing of controlled substances in a community setting	Prospective analysis	Survey given to physicians before and after implementation of electronic prescribing of controlled substances (EPCS)	<ul style="list-style-type: none"> 70/102 prescribers sent at least one controlled substance Found to be less burdensome than previously thought Barrier is limited pharmacy participation and unreliable technology instances 	Journal of American Medical Informatics Association	B

Table 4. Summary of Articles: Limitations

Year	Author	Title	Design	Intervention	Findings	Source	Study Grade
2005	Galt, Siracuse, Rule, Clark, Taylor	Physician Use of Hand-held Computers for Drug Information and Prescribing	Randomized, controlled trial	Primary care physicians were given a PDA to prescribe and the error rates were assessed	<ul style="list-style-type: none"> Use for hand-held devices show some validity Physicians feel that they can see more patients Important to have positive learning-related attitude Proper training needed 	Advances in Patient Safety: From Research to Implementation (Book)	B
2005	McMullin	Standardization is Necessary in the Methods to Assess the Value of Electronic Prescribing Systems	Post-hoc analysis	Follow-up study on drug utilization and costs based on script volume as reported by use of an electronic prescribing system	<ul style="list-style-type: none"> While the study mainly focuses on the use of one particular e-prescribing program, it mentions the need for standardization to better accurately assess the value of certain programs over another. 	JMCP	B
2006	Grimsmo	Electronic prescriptions – without side-effects?	International literature analysis	Literature review	<ul style="list-style-type: none"> Need to continually prepare for unknown risks with electronic prescribing <ul style="list-style-type: none"> Need for constant system testing and evaluation after implementation New system may change or unintentionally put aside well-established safety routines 	Norwegian Article	B
2006	Halamka, Ascenzo, Bates, Berry, Debor, et al.	E-Prescribing collaboration in Massachusetts: early experiences from regional prescribing projects	Report	None	<ul style="list-style-type: none"> Evaluation of barriers to e-prescribing Previous negative technology experiences, costs, lost productivity, competing 	Journal of the American Medical Informatics Association	C

					priorities, change management issues, interoperability limitations, IT requirements, standards limitations, waiting for an “all-in-one solution” and confusion about competing product offerings		
2007	Donyai, O’Grady, Jacklin, Barber, Franklin	The effects of electronic prescribing on the quality of prescribing	Prospective intervention analysis	Recording of pharmacy interventions during a 4 week period before and after implementation of electronic prescribing	<ul style="list-style-type: none"> ● UK study ● E-prescribing reduced pharmacist intervention (73 →45) as well as prescribing errors (94 → 48) ● Pharmacy needs to develop ways to complement use of electronic prescribing rather than duplicate the benefits of it 	British Journal of Clinical Pharmacology	B
2007	Gerstle, Lehmann	Electronic prescribing systems in pediatrics: the rationale and functionality requirements	Technical report	Report discusses use of e-prescribing in pediatrics	<ul style="list-style-type: none"> ● Evaluates e-prescribing in all aspects (from costs to technical issues) 	Pediatrics	B
2007	Grossman, Gerland, Reed and Fahlman	Physician’s experiences using commercial e-prescribing systems	Discussion	44 discussions from respondents in two-person teams in 26 organizations via telephone	<ul style="list-style-type: none"> ● 2/3 of practices used EMR (integrated system) ● 1/3 stand-alone system ● Issue with maintaining patient medication lists ● Lack of decision support ● Difficulty obtaining accurate patient-specific formulary information ● Limited connectivity with pharmacies and mail-order PBMs ● Not enough staff to maintain and support IT after implementation ● All respondents believe e-prescribing improves safety and quality while increasing practice efficiency 	Health Affairs	B
2007	Scalise	The case for e-prescribing	Analysis	None	<ul style="list-style-type: none"> ● Lost productivity due to time required to print PDA generated prescriptions and fax pharmacies (applies to controlled medications) ● Program functionality confusion ● Cost – software/hardware cost 	Hospital and Health Networks	B

					<p>ranges from \$1,500 - \$4,000/physician</p> <ul style="list-style-type: none"> • Advanced systems with complex alerts and reminders are \$29,000/physician in the first year and \$4,000 annually thereafter • Waiting for an all-in-one solution before investing in a product 		
2007	Vanderbush, Anderson, Fant, Fujisaki, Malone, Price, et al.	Implementing Pharmacy Informatics in College Curricula: The AACP Technology in Pharmacy in Education and Learning Special Interest Group	Discussion	None	<ul style="list-style-type: none"> • Stressing the importance of giving students more awareness and use of informatics in the practice of pharmacy while still in school. 	American Journal of Pharmaceutical Education	D
2008	Cusack	Electronic health records and electronic prescribing: promise and pitfalls	Analysis	Survey	<ul style="list-style-type: none"> • Evaluation of implementation issues • Push for investment due to pay-per-performance incentives <ul style="list-style-type: none"> • However, adopting e-prescribing is a difficult task due to costly investment and systems disruption 	Obstetrics and gynecology Clinics of North America	B
2008	Devine, Wilson-Norton, Lawless, Hansen, Hollingworth, Fisk, Sullivan	Implementing an Ambulatory e-Prescribing System: Strategies Employed and Lessons Learned to Minimize Unintended Consequences	Analysis	None	<ul style="list-style-type: none"> • CPOE improves quality of care and reduces med errors <ul style="list-style-type: none"> • Need an integrated, community-based system for adoption • Need for ongoing training • Key is team-oriented culture (bridge between all points of healthcare) 	Advances in Patient Safety: Alternative Approaches (Volume 4: Technology and Medication Safety)	B
2008	Rupp, Warholak	Evaluation of e-prescribing in chain community pharmacy practice recommendations	Descriptive, nonexperimental, cross-sectional study	Self-administered survey and interviews of key pharmacy operations and information technology management	<ul style="list-style-type: none"> • 1,094 surveys returned. • E-prescriptions were preferred in each of the 7 desired outcomes of care. • Benefits: legibility, improved speed on efficiency of processing Disadvantage: prescribing errors due to lack of training 	Journal of the American Pharmacists Association	B
2009	Balfour, Evans, Januska, Lee, Lewis, Nolan, Noga, Stemple, Thapar	Health Information Technology – Results from a Roundtable Discussion	Discussion	None	<ul style="list-style-type: none"> • Challenges to adoption of e-prescribing are high costs, resistance to change, misaligned incentives and fractured payment system • Benefits: avoid costs from 	JMCP	C

					<p>adverse drug events</p> <ul style="list-style-type: none"> • Impact on cost exceed a saving of \$800 million over a 5 year period by prescribers, dispenses and beneficiaries • E-rx transactions have risen 3x from 2007 to 2008 with over 100 million transactions (started with 700,000 in 2004) 		
2009	Warholak, Rupp	Analysis of community chain pharmacists' on electronic prescriptions	Descriptive, nonexperimental, cross-sectional study	Panel of pharmacists reported medication therapy interventions using a standardized protocol	<ul style="list-style-type: none"> • Reviewed reasons why interventions were made based on whether they were new or refill prescriptions. • Most common reason: omitted information from physician (especially directions) or dosing errors 	Journal of the American Pharmacists Association	B
2010	Savage, Cornford, Klecun, Barber, Clifford, Franklin	Medication errors with electronic prescribing (eP): Two views of the same picture	Structured, quantitative retrospective study AND qualitative retrospective method	Interviews with staff and patients on medication incidents in London hospitals two years after e-prescribing implementation OR retrospective analysis of data through electronic system	<ul style="list-style-type: none"> • Qualitative studies provided more understanding of processes and insight as to why medication errors happen • Electronic prescribing errors resulted from improper med reconciliation at admission and department transfer • Lack of allergy warnings to get drug interactions • Non-user friendly order entry screen and lack of decision support 	BMC Health Services Research	B
2011	Frolich, Zorina, Fontana, Kullak-Ublick, Vollenweider, Russmann	Evaluation of medication safety in the discharge medication of 509 surgical inpatients using electronic prescription support software and an extended operational interaction classification	Cross-sectional study	Retrospective identification of drug interactions in patients' discharge medication	<ul style="list-style-type: none"> • 2,558 of 2,729 prescriptions generated interaction alerts and 1,849 comments <ul style="list-style-type: none"> • 10 high danger (contraindications) based on ORCA criteria • 551 average danger alerts based on ORCA criteria (77 provisionally contraindicated combos, 310 conditional and 164 minimal risk of adverse outcomes) • 56 did not have recommended dose adjustment for impaired renal function • Need to reduce over-alerting 	European Journal of Clinical Pharmacology	B

					and improve usability to be more efficacious in preventing adverse drug events		
2011	Grossman, Cross, Boukus, Cohen	Transmitting and processing electronic prescriptions: experiences of physician practices and pharmacies	Qualitative analysis	Telephone interviews with physician practices, community pharmacies and mail order pharmacies using Surescripts	<ul style="list-style-type: none"> • Most parties were satisfied with the use of electronic transmission but there were system limitations that prevented electronic transmission and required a fax or phoned in prescription. • Inconsistent renewal processes by physicians required pharmacy staff to complete or edit fields 	Journal of American Medical Informatics Association	B
2011	Liu, Burkhart, Bell	Evaluation of the NCPDP Structured and Codified Sig Format for e-prescriptions	Retrospective cross-sectional study	Evaluation of ambulatory e-prescriptions based on the actual words used by prescribers in the sig field to the equivalent terms in the designated terminology	<ul style="list-style-type: none"> • 95% of sigs were correctly represented • Some ambiguities – but mainly from multi-step instructions • Most errors were administration timings and dose delivery methods 	Journal of the American Medical Informatics Association	B
2011	Nanji, Rothschild, Salzberg, Keohane, Zigmont, Devita, Gandhi, Dalal, Bates, Poon	Errors associated with outpatient computerized prescribing systems	Retrospective cohort study	Clinical panel review of 3850 computer generated prescriptions for medication errors, potential adverse drug events, and rate of prescribing errors	<ul style="list-style-type: none"> • 11.7% error rate – 35% of those errors were considered potential adverse drug events. • Main error – omitted information 	Journal of American Medical Informatics Association	B
2011	Redwood, Rajakumar, Hodson, Coleman	Does the implementation of an electronic prescribing system create unintended medication errors? A study of the sociotechnical context through the analysis of reported medication incidents	Exploratory study of survey collection	Survey results and determine if sociotechnical incident (due to human interactions with the system) or non-sociotechnical	<ul style="list-style-type: none"> • 15% (of 485) were sociotechnical issues in the hospital setting • Increased incidence on Sundays • Need to improve training and work out unintended problems 	BMC Medical Informatics and Decision Making	B
2011	Saverno, Hines, Warholak, Grizzle, Babits, Clark, Taylor, Malone	Ability of pharmacy clinical decision-support software to alert users about clinically important drug-drug interactions	Qualitative study	On-site visits to analyze and evaluate pharmacy information systems using predetermined patient's and orders	<ul style="list-style-type: none"> • Only 28% of the pharmacies were able to correctly identify eligible interactions and non-interactions. • Comprehensive system updates are perpetually needed. 	Journal of American Medical Informatics Association	B
2012	Banks, Galvez	E-Prescribing Adoption: A Prescription for Progress	Analysis	None	<ul style="list-style-type: none"> • Evaluation of where e-prescribing is and how it is helping prescribers and pharmacists improve patient care • Standardization by states for e-prescribing 	Health IT Buzz	B

					<ul style="list-style-type: none"> • North Dakota – given \$6 million to adopt information technology and e-prescribing and has had a 42% increase in active pharmacy adoption • Need for investment and positive environment to get adoption • Need to reduce barriers for independent pharmacies and rural areas 		
2012	Salmon, Jiang	E-prescribing: History, Issues and Potentials	Review	None	<ul style="list-style-type: none"> • Discusses pitfalls of e-prescribing • Emphasizes benefit gained from adjusting dosages 	Online Journal of Public Health Informatics	B
2013	Lander, Klepser, Cochran, Lomelin, Morien	Barriers to electronic prescribing: Nebraska pharmacists' perspective	Intervention	Interview with pharmacists or pharmacy managers from non-participating pharmacies	<ul style="list-style-type: none"> • 43% delaying implementation due to transaction fees and maintenance costs • Lack of demand from customers and prescribers to implement it due to high start-up costs • 39% didn't understand the benefits of e-prescribing and unsure of how to implement it 		B
2013	Marceglia, Mazzola, Bonacina, Targuini, Donzelli, Pincioli	A comprehensive e-prescribing model to allow representing, comparing and analyzing available systems	Literature review	None	<ul style="list-style-type: none"> • Mentions that there is still a variety of e-prescribing systems and that there is a need for model-based implementation to increase quality of care and effectiveness of care delivery 	Methods of Information in Medicine	C

3. Results

A total of fifty-six peer-reviewed articles were included in this review. Trends show that most clinicians view e-prescribing positively despite some limitations. Limitations of e-prescribing include cost of implementation and maintenance, insufficient training, and lack of standardization. As more legal regulations come into effect promoting standardization, there is greater incentive to invest in integrated e-prescribing systems as well as promote clinician adoption.

Cost Effectiveness

Illegible prescriptions and drug interactions have been attributed to causing approximately 7,000 deaths per year [59]. E-prescribing has been shown to reduce prescribing errors and increase long term benefits [1]. One health system in Michigan saved \$3 million annually with the implementation of e-prescribing [59]. Some of the benefits include: better legibility, less prescription duplications, and improved efficiency of processing in dispensing medication. In 2010, Kaushal and colleagues showed that error rates when converting from paper prescriptions to electronic prescriptions decreased by sevenfold [2]. Furthermore, pharmacist, physician, nurse and staff efficiency has been shown to improve with e-prescribing [20]. In addition, the use of electronic prescribing has been shown to increase patient medication compliance, which then further decreases the number of subsequent hospital visits [18]. An example is a 2011 study that showed for every \$10 increase in a patient's initial hyperlipidemia medication, the likelihood for a patient to be at goal decreases by 5% [11]. A second study showed that for every dollar invested to increase medication adherence, there is a potential to save \$3-\$10 in medical costs [19]. For some health plans, this could be a total saving of \$14 billion/year.

While the potential savings seem to be substantial, one of the biggest reasons for the lack of implementation of e-prescribing is the cost investment. The Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 was developed to pave the way towards making a technological approach to healthcare by setting aside \$22 billion for EHR utilization [8]. Once EHRs have been successfully implemented within a clinical setting, the progression is to focus on electronic prescribing. However, with the HITECH Act only focusing on EHR implementation, institutions are faced with having to invest their own funds in an e-prescribing system. In addition, there are no set standards that are required for an e-prescribing program and thus institutions and facilities have freedom in the type of system they choose. A 2007 study by Scalise and colleagues revealed that the cost to implement a basic e-prescribing program ranges from \$1,500 - \$4,000 per physician. The price for an advanced system with alerts, reminders and system integration is \$29,000 per physician in the first year and \$4,000 per physician every year

thereafter [9]. While there is a huge difference in pricing, multiple studies have shown that physicians will utilize the system more if it is user-friendly, integrated to have access to patient files and provides clinical and formulary decision support options [10,11,12,13,14]. With many different commercially systems available and a multitude of different options and features, an issue arises in choosing a system and validating the investment cost. This decision is further complicated by the need to assess costs to train employees, technological maintenance of the program and ensure that the system is reducing error and providing a return on investment (ROI). Studies show that while e-prescribing software has been shown to be cost-effective for practices of all sizes, the time frame for a return on investment varies. Larger practices achieve a quicker ROI [20]. Therefore, it is not difficult to imagine that many institutions are awaiting an "all-in-one" package and delaying the need to invest in electronic prescribing [15].

Pharmacies are also hesitant to implement e-prescribing into their workplace. A recent 2013 study by Banks and Galvez assessed that pharmacies did not want to spend initial start-up costs as well as maintenance and transaction fees to insurers [27]. Furthermore, the lack of demand for use from physicians or patients promotes a delay in adoption. Some pharmacies commented that they didn't understand the benefits to be gained from using e-prescribing while others reported that the costs didn't outweigh the benefits. Additionally, independent pharmacies or pharmacies in rural areas have identified lack of prescription volume as a reason not to invest in such a costly program. On the other hand, with the HITECH Act of 2009, many states are providing financial assistance to offset those costs. In Tennessee, the state's pharmacists association allocated \$675,000 in grants to 124 independent, community pharmacies [28]. The state of North Dakota dispersed over \$6 million to promote the adoption of information technology and has seen a 42% increase in active pharmacy utilization [28]. Other states are following suit and offering state appropriations, grants and revolving loans so that smaller pharmacies can meet their technological needs, especially with the changes in state and federal requirements advocating for e-prescribing.

Incentives for pharmacies and institutions to implement adoption can result in direct cost savings. A 2013 study by Radley et al. showed that the decrease in prescription error from e-prescribing caused a 12.5% reduction in medical errors in over 4,700 hospitals in the United States [41]. This translates to cost savings for over 17 million errors per year. Utilization of e-prescribing with formulary decision support can further reduce hospital visits and pharmacy spending on medication. Findings from recent articles revealed that physicians are more likely to prescribe tier 1 (generic) drugs [10,25,26] and patients are more likely to purchase the tier 1 medication prescribed when it requires lower copayment. Furthermore, the resulting decrease in utilization of tier 2 (brand name) or other specialty drugs can result in savings of \$845 per patient based on a 20%

e-prescribing rate [13]. Therefore, savings can substantially increase with a higher e-prescribing adoption percentage. Pharmacies may also achieve savings by not having to purchase specialized and expensive inventory that is either a rarely dispensed item or one that a patient rarely will purchase due to its high copayment. Stocking such unpopular items results in loss of income due to items not being able to be returned to the manufacturer or becoming expired.

Clinician Adoption

The 2013 Medicare eRx Payment Adjustment provides an incentive for physicians who serve Medicare patients to switch to e-prescribing. Physicians who do not switch to e-prescribing receive a 1.5% decrease in payment on all Medicare Part B services [5]. Furthermore, this adjustment increases to 2% in 2014 [5]. A major component for the continuing success and development of e-prescribing is its adoption by physicians, pharmacists, and any other healthcare providers. Many studies have discussed the mixed positive and negative perceptions on adoption and how negative attitudes are preventing the utilization of e-prescribing. Recent studies have shown that physicians' perception of e-prescribing after efficient implementation is viewed as very efficient and easy to use [31, 32, 39]. A 2007 study analyzed the time to track both physician and staff members when using an integrated system. The results showed e-prescribing had no disruption to workflow and had no statistically significant increase in time when compared to handwritten prescriptions [4, 40]. The use of computerized physician order entry (CPOE) in hospitals to write inpatient prescriptions was found to decrease the likelihood of a prescription error in an acute setting by 48% [41]. While cost was one of the main factors contributing to negative attitudes, there were other factors as well. Lack of adequate training, clinical support, formulary support, or software issues were identified as major deterrents [29, 32, 36]. With the exception of lack of training, most barriers were related to the technology. Physicians reported issues of limited connectivity with pharmacies requiring multiple transmissions of the same prescription and pharmacies reported issues in receiving the same prescription more than once [10, 32]. This transmission issue created an increased workload for both physicians and pharmacists. If resolution of these issues is possible in the future, most physicians will have a more positive mindset towards electronic prescription adoption. For example, physicians with an integrated e-prescribing system who had access to their patient's medication profile were more likely to review it before prescribing a new medication. The use of this feature gave the physician more awareness of potential duplication in therapy, potential allergies and drug-drug interactions [2, 36]. Increased awareness in this manner gives physicians a better ability to evaluate and diagnose their patients.

Studies on pharmacist's perceptions revealed that they felt e-prescribing may decrease errors and increase efficiency for physicians, but required as much pharmacist intervention as would normally be provided due to omitted information or dosing errors on prescriptions sent electronically [30, 32]. Additionally, some pharmacists negatively viewed e-prescribing systems due to the over utilization of alerts. On the other hand, several studies showed that pharmacists perceived e-prescribing positively noting better legibility, improved processing time and efficiency as benefits [1].

Although clinician views on the adoption of e-prescribing are mixed, there is a consensus from all groups that proper training is required to improve the efficiency of the dispensing process [29, 30, 32]. Clinicians may receive incomplete information from time to time which results in distrust in the e-prescribing system. For example, a physician may find incomplete documentation of a patient's medical history [26]. Findings from a 2011 study by Nanji and colleagues showed that for the 45 pharmacy interventions required for 3,850 computer generated prescriptions, thirty five percent of those interventions resulted from omitted information or potential adverse drug events [17]. Findings from another study in 2012 revealed that 153 pharmacy interventions were needed for 1,678 new prescriptions to address omitted information, excessive quantity, etc. [40]. Greater data accuracy and completeness is needed to increase clinician confidence in e-prescribing.

Clinicians also feel that some prescriptions required a faxed or phoned in prescription, citing system limitations especially with controlled substances preventing electronic transmission [32]. As of 2010, the DEA has authorized the use of electronic prescribing of controlled substances (EPCS) [34, 35]. However, most pharmacies have not yet adopted the utilization and will not allow physicians to electronically prescribe them and therefore, must submit a fax or phoned in prescription [35]. While controlled substances only make up 11% of all prescriptions issued, they are prescribed by 90% of all physicians [34]. This creates an increase in workflow for both physicians and pharmacies. However, the adoption of EPCS is due to the extra technology regulations to ensure secure transmission by the DEA. Many systems are still in the process of being updated to include these operational security issues. Hopefully, once in effect, the issue of controlled substances will be one less barrier for the proper utilization of e-prescribing.

In addition to studies on controlled substances, studies are being conducted to examine whether e-prescribing can help to efficiently manage patients and their disease states more so than paper prescriptions. A 2011 study by Michelis and colleagues analyzed the effects of using electronic prescriptions to better manage hyperlipidemia patients [11]. Patients that were given an electronic prescription were 59% more likely to reach their LDL goals. The study revealed that the utilization of formulary decision support helped patients to obtain their low cost

prescriptions. Similarly, a second 2009 study by Smith et al. discussed how diabetes patients benefited from e-prescribing through the reduction of errors such as correct product selection through more legible prescriptions (i.e. Novolog versus Novolin or glipizide versus glimeperide)[23]. Furthermore, results revealed that clinical decision support helped physicians and pharmacists better predict drug interactions and assisted with updating dosage regimens. Other studies have also analyzed the use of electronic prescriptions for oral chemotherapy regimens[42]. Authors developed a built in field for weight and body surface area to allow for more accurate dosing. Findings revealed that over six hundred clinicians readily accepted and utilized e-prescribing to better enhance oral chemotherapy safety. As illustrated, several studies have highlighted positive benefits in the use of e-prescribing, however, an equal number of studies point to its limitations.

Barriers to Implementation (Limitations)

A major concern that has prohibited the widespread adoption of e-prescribing is the lack of standardization or requirements related to it [43,57]. This makes it difficult to assess the value of the different systems available. There are also inconsistencies in the perception of e-prescribing. Some systems are stand-alone and used only to write prescriptions while others are integrated and allow access to patient profiles. Some systems have a combination of varying clinical decision support and formulary decision support while others have none. In 2013, Marceglia and colleagues discussed potential modeling methods to better standardize e-prescribing systems by breaking down the six phases of the e-prescribing process [57]. However, they recognized that it is a difficult task due to the large heterogeneity among functionalities and performances of existing systems. There is even variation in the sig codes designated for each system on how to use short codes to type in directions for electronic prescriptions [44]. The National Council for Prescription Drug Programs (NCPDP) developed a structured and codified sig format that has been shown to be 95% effective. However, not all systems and institutions utilize this format because it is merely a recommendation and not a guideline that is enforced.

The second concern about e-prescribing relates to sociotechnical error, or an error caused only by human interaction when using the system [45]. It has been suggested that institutions and pharmacies develop an auditing system to ensure staff members are using the system correctly [28]. Examples of sociotechnical errors are omitting information in a certain field, inappropriate use or selection of default doses, or a system alert that causes a distraction and interruption of workflow that ultimately causes a prescription error. For example, over-alerts from e-prescribing systems have been shown to be distractions hindering pharmacists' ability to discern true drug interactions. In 2011, Saverno and colleagues analyzed

pharmacy e-prescribing systems in hospital and community settings and found that only 28% were able to correctly identify eligible interactions [37]. A second 2011 European study showed that 93.7% of 2,729 electronic prescriptions generated an interaction alert. Of those alerts, only 10 were shown to have a true contraindication and 551 average danger alerts with some risk of adverse outcomes [38]. Therefore, pharmacy systems usability needs improvement so that pharmacists can more accurately prevent adverse drug events. These changes can drastically improve pharmacist outlook on e-prescribing. Although sociotechnical errors are a concern, findings from Redwood's 2011 study showed that out of 485 medication incidents, only 15% were attributed to e-prescribing [45]. While this may be viewed as a small amount, future efforts should aim to resolve these new issues and ensure that other issues do not arise from its use.

The third major concern related to e-prescribing is the lack of adequate training for clinicians. Many studies provide support for the implementation of a pharmacy informatics team to develop training education programs as well as mediate other technological issues, such as system maintenance and upgrades [26,37]. With clinical guidelines constantly changing, systems need to be continually updated to reflect those new recommendations. In addition, the informatics team may develop upgrades to make the system more user-friendly or serve as the system liaison to prescribers. For example, some prescribers have indicated that a limitation to e-prescribing was physical access to a computer, which decreased time for patient interactions [47]. However, with technology also constantly changing, concerns related to lack of training may be addressed through the development of application upgrades to use on hand-held portable devices [46]. The upgrades could be developed by a pharmacy informatics team to help minimize the physical dependence on a desktop computer and allow prescribers to access patient EHRs and write e-prescriptions in places that have an Internet connection. In 2007, Donyai and colleagues provided a discussion on an upgrade developed to allow indication of an "as needed" (PRN) prescription in a hospital system to minimize administration and prescription errors by 48.9% and improve communication between prescribers and nurses [48]. The upgrade also reduced the need for pharmacy interventions by 38.3%.

Lastly, not all e-prescribing systems have the capability to adjust dosages for special populations such as pediatric, elderly, or those with hepatic or renal impairments [38,55]. While studies have shown the potential benefits for such features, Frolich and colleagues showed that recommended dosing was not altered for renally impaired patients. Furthermore, in 2013, Johnson and colleagues reported that there was limited data to show a significant role for e-prescribing in the pediatrics community due to the lack of pediatric functionality [18]. However, the study also highlighted the adoption of e-prescribing emphasizing that changes to current e-prescribing systems are needed.

4. Conclusion

An expansion of e-prescribing is expected in the future. Despite limitations related mainly to cost investment and inconsistency of technological systems, many studies are emphasizing the benefits of e-prescribing, which include a decrease in prescription errors, improving efficiency and prospective cost savings as a result of utilization. Although studies revealing the cost effectiveness of e-prescribing are substantial, those effects will be seen over time after efficient training has been achieved. In one study, Bartlett and colleagues had 28 physicians undergo a two week training session using an integrated system with clinical and formulary decision support on mock patients. After timed assessments, the study showed that user ability would not be a barrier for adoption as long as there was a user-friendly system and a thorough one-on-one training with troubleshooting support for implementation issues [9,60]. However, it is realistically difficult to require clinicians to spend long periods of time training and to expect them to overcome the barrier of investing in such a highly integrated system. The Center for Improving Medication Management (CIMM), along with the cooperation of several physician groups such as the American Medical Association, provides a clinical guide to e-prescribing with annual updates [62]. The guide helps to stress the clinical importance of e-prescribing as well as any updates to its use. While it is a good resource, it is not highly well-known and is limited to prescribers. Future efforts should include a target towards other groups involved in the process, such as nurses, physician assistants and pharmacists.

Adoption of e-prescribing can be stimulated by organizational commitment from all members of the healthcare team and technological support teams [9,56]. This includes support from payers that may clearly communicate the benefits of e-prescribing, such as initiating a pay-for-performance program to provide a strong incentive. E-prescribing vendors can and should also proactively reach out to clinicians to ensure increased use over time. Informatics teams should develop new applications to keep the technology up-to-date and more user-friendly. Quality management programs are needed to promote the standardization of e-prescribing. Currently, Surescripts is one company aiming to help provide information on this process with the Quality Program. Their goal is to improve the quality of the e-prescribing process by assessing all aspects and work on standards, certification, network monitoring and providing customer support [61]. Surescripts works with physician groups, system vendors and pharmacies to collect data to reduce the amount of time a problem is identified and solved. However, the Surescripts' program does not include every provider group, vendor and pharmacy because there are no clear laws as to what is required for the e-prescribing process. The program needs legislative support to ensure that those involved are required to be regulated by a third party.

Positive perception of e-prescribing will be the key to increasing adoption by healthcare professionals. Many physicians and pharmacists seem to focus on the barriers as opposed to the benefits. It is important to facilitate e-prescribing adoption by targeting factors that are salient to each group of clinicians. Further investment in a pharmacy informatics team, especially within institutions, can address these issues of implementation, training, and development of the continuous technological maintenance that e-prescribing systems require. Although a valuable resource, pharmacy informatics, specifically e-prescribing is still relatively a new concept and further assessments are warranted.

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